ASD TR 62-7-787
ASTIA NR.

ASD Technical Report 62-7-787
May 1962

MOTOR CASE FABRICATION FROM WIDE CLOSE-TOLERANCE STEEL SHEETS

Prepared by
Bernard B. Moss

MISSILE AND SPACE SYSTEMS DIVISION
Douglas Aircraft Company, Inc.
Santa Monica, California

Contract: AF33(600)-39653
ASD-7-787

December 1961 - April 1962

Six missile motor cases of the second stage Nike-Zeus configuration were manufactured by roll-and-weld fabrication methods. In these cases the processing technique of resistance seam welding heat treated components was employed. All six satisfactorily met the proof test at a theoretical hoop stress of 237,000 psi.

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MANUFACTURING TECHNOLOGY LABORATORY

ASD, AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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CONTRACT: AF 33(600)-39653
ASD-7-787

MISSILE AND SPACE SYSTEMS DIVISION

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Approved by J L Waisman
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ABSTRACT-SUMMARY

ASD TECHNICAL REPORT 62-7-787
May 1962

MOTOR CASE FABRICATION FROM WIDE CLOSE-TOLERANCE STEEL SHEETS

Prepared by Bernard B. Moss
DOUGLAS AIRCRAFT COMPANY, INC.

This report covers the end use of the AISI 4340 steel sheets remaining at the Douglas Aircraft Co., Torrance facility at the completion of the Symposium on Wide Close-Tolerance Steel Sheets held at Pacific Palisades, June 27 and 28, 1961. It is published as supplemental to the Douglas Aircraft Company presentation at the symposium.

Six missile motor cases of the second stage Nike-Zeus configuration were manufactured by roll-and-weld fabrication methods. In these cases the processing technique of resistance seam welding heat treated components was employed. All six satisfactorily met the proof test at a theoretical hoop stress of 257,000 psi.

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FOREWORD

This report covers all work performed by the participating contractor Douglas Aircraft Company, Inc., from December 1961 to April 1962. The report was released by the author in May, 1961 for publication as ASD Technical Report 62-7-787.

This project was negotiated by the Fabrication Branch, Manufacturing Technology Laboratory, ASD, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. The assigned project engineer for ASD, Air Force Systems Command was Mr. Robert T. Jameson, ASRCTF. The assigned project engineer for Douglas Aircraft Company, Inc., Missile and Space Systems Division, was Mr. Bernard B. Moss, senior specialist. This disclosure is based on work performed by the contractor, under Air Force Contract AF33(600)-39653.

The primary objective of the Fabrication Branch of the Manufacturing Technology Laboratory is to increase producibility and to improve the quality and efficiency of the fabrication of aircraft, missiles, and components thereof. This report is being disseminated in order to advise of the experience gained in the use of wide steel sheets, thereby assisting industry in reducing costs and improving reliability and efficiency and giving "MORE AIR FORCE PER DOLLAR".

Your comments are solicited on the potential utilization of wide steel sheets as applied to present or future production programs. Suggestions concerning additional manufacturing methods development required on this or other subjects will be appreciated.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Arden B Hughes

ARDEN B. HUGHES
Lt. Colonel, USAF
Chief, Manufacturing Technology Laboratory
Directorate of Materials & Processes

TABLE OF CONTENTS

SECTION I

INTRODUCTION

INTRODUCTION

This report is supplemental to the Douglas Aircraft Company presentation at the Symposium on Wide, Close-Tolerance Steel Sheets which was sponsored by the United States Air Force, and was held at Pacific Palisades, June 27 and June 28, 1961. The proceedings and presentations were published in October, 1961 as ASD Technical Report 61-7-787a. The publication of this supplemental report serves to put on record the end use of the wide steel sheets, alloy AISI 4340, that remained in the possession of the Douglas Aircraft Company at the conclusion of the above Symposium.

It was previously demonstrated that a motor case cylinder could successfully be fabricated by a 360° single roll, provided a wide enough sheet is obtainable. The original objective in demonstrating the feasibility of eliminating a longitudinal fusion weld by the use of the wide steel sheet furnished by this contract was achieved. This procedure required special tooling which was no longer available when the second set of motor cases was released for production. Each sheet was therefore sheared to the width required for production by the standard Douglas roll-and-weld fabrication procedure which employs two longitudinal fusion welds. The necessity of following this procedure in no way detracts from the success of the United States Air Force sponsored program which resulted in the extra wide sheets furnished, since the Douglas fabrication techniques and controls, are directly applicable to the double or single longitudinal weld procedure, provided proper tooling is available.

The most significant change in the processing since the previous report was prepared is the weld-after-heat-treatment sequence. The assembly sequence of the three main motor case components, the cylinder, dome, and the cone, as previously reported, was to roll cylinder half shells, longitudinally butt fusion weld, size the cylinder, fit the dome and cone to the cylinder and install by resistance seam welding, and then heat treat the entire structure. The feasibility of resistance seam welding the dome and cone to the cylinder after they have been individually heat treated was established experimentally, and then applied to the production line motor cases. The six motor cases covered by this report were handled as six routine production cases, released for production, after the weld-after-heat-treat fabrication sequence was firmly established as the standard processing sequence.

SECTION II

FABRICATION

FABRICATION

The fabrication of the shell was unchanged with regard to the basic processing and handling, and is adequately covered in the previous report. The cone is machined from a die forging and this sequence is unchanged. The deep drawing of the dome was changed in that a new Douglas design hydraulic forming press was used. This press incorporates the concept of a variable hold-down pressure of the blank thereby permitting more consistent control of the material thickness during the forming operation, than is normally obtained with the conventional type forming press.

The heat treatment of the components is carried out in a Gantry type, inverted pit furnace employing the following heat treatment procedure.

(a) Austenitize for 1-1/2 hours at 1525°F in an endothermic atmosphere.

(b) Quench in oil.

(c) Temper for two hours at 475°F.

After heat treatment, the end closures, the dome and the cone, are fitted to the cylinder and installed by resistance seam welding. This sequence required considerable development work in establishing proper weld settings, and the required processing control. It has resulted in a motor case with increased reliability, permitting the proof testing to approximately 0.05% permanent set (a theoretical calculated hoop stress of 237,000 psi in the cylinder).

SECTION III

INSPECTION

INSPECTION

The final inspection of the completed assembly is unchanged from what was previously reported. The welds are x-rayed and are inspected magnetically. Figure 1 shows a motor case positioned on the magnetic particle inspection unit in the normal position for inspecting. The final dimensional check is carried out electronically in a unit specifically designed for this purpose. Figure 2 shows a motor case on the inspection stand in the inverted position with the cone end up.

SECTION IV

PROCESS CONTROL

PROCESS CONTROL

The main areas of processing control at which monitoring includes tensile test coupons are the incoming receiving inspections, the fusion welding, the resistance seam welding and the heat treatment. The incoming receiving inspection and testing is unchanged from what was previously reported.

The logitudinal fusion welds are identified as "A" and "B". A tensile coupon is prepared from the trim area of the cylinder across each weld with the weld bead at the reduced section. This is illustrated in Figure 3. The coupons proceed through the same heat treatment as the cylinder and are then tested. Table I give the mechanical strength data of the fusion weld control coupons for the six motor cases covered by this report.

At regular intervals the seam welder settings for any specific motor case configuration are checked by welding a special test panel, using heat treated steel sections that are the same gage as the mating motor case components. Strips of the panel are then tested in tension. This special test coupon is illustrated in Figure 4. Due to the offset character of the test specimen and the resulting bending moment at the nugget the strength values obtained do not give an absolute value of the strength at the joint. However the test has been found to be very useful in monitoring the resistance seam weld settings. The data for the six motor cases, are given in Table 2, and are included to illustrate the narrow scatter, which points up the close control that can be exercised in this type of closure joining.

The heat treatment cycle and the atmosphere control are monitored by including tensile coupons with each heat treat load. These are compared with the strength of copper plated coupons included with the same load. Table 3 gives the heat treatment control data for the six cylinder components of the motor cases covered by this report.

SECTION V

PROOF TESTING

PROOF TESTING

As has been previously indicated the completed motor case is proof tested by pressurizing with oil to a theoretical hoop stress in the cylinder of 237,000 psi. This results in a permanent set in the cylinder of approximately .05%. The data covering the proof testing of the six motor cases is given in Table 4.

SECTION VI

TABLES

TABLE I

MECHANICAL PROPERTIES AT "A" AND "B" FUSION WELDS
NIKE-ZEUS - SECOND STAGE - P/N 5682968

MOTOR CASE NO.	WELD	YIELD STR. PSI x 10^{-3} 0.2 OFFSET	ULTIMATE STRENGTH PSI x 10^{-3}	ELONGATION % IN 2 INCHES
RC141	A	217.2	255.5	6.0
	B	217.5	255.6	6.0
RC142	A	214.8	250.8	6.0
	B	219.6	259.2	7.0
RC143	A	NOT AVAILABLE		
	B	NOT AVAILABLE		
RC144	A	218.4	261.1	7.0
	B	217.7	256.9	7.0
RC145	A	220.5	260.8	7.0
	B	220.4	260.1	7.0
RC146	A	221.1	257.8	7.0
	B	224.2	263.9	6.0

TABLE 2

TENSILE STRENGTH ON RESISTANCE SEAM WELD CONTROL TEST COUPONS
NIKE-ZEUS SECOND STAGE - P/N 5682968

MOTOR CASE NO.	WELD	ULTIMATE STRENGTH PSI $\times 10^{-3}$		
RC141	Dome	175.6,	184.0	183.2
		178.8,	181.0	180.1
	Cone	197.4	202.2	
		197.1	196.7	
R142	Dome	195.9	193.7	195.3
		196.6	192.7	197.5
	Cone	195.1	193.6	
		195.1	194.2	
RC143	Dome	192.2	195.6	
		194.7	194.7	
	Cone	N O T A V A I L A B L E		
RC144	Dome	150.1,	191.6,	151.9
		193.7	199.5	165.8
	Cone	202.6		
		201.8	200.3	
		200.3	198.1	
RC145	Dome	195.6	194.4	
		193.0	188.3	
	Cone	202.0	204.8	202.0
RC146	Dome	177.0	178.0	
		181.3		
	Cone	N O T A V A I L A B L E		

TABLE 3

MECHANICAL PROPERTIES OF HEAT TREATMENT CONTROL COUPONS
NIKE-ZEUS - SECOND STAGE - P/N 5682968

MOTOR CASE NO.	COUPON CONDITION	YIELD STR, PSI $\times 10^{-3}$ 0.2 OFFSET	ULTIMATE STRENGTH PSI $\times 10^{-3}$	ELONGATION % IN 2 INCHES
RC141	Unplated	211.4 213.3 210.7 209.6	253.1 253.4 250.4 251.6	6.5 6.5 6.5 6.5
	Copper plated	219.9 225.8	262.1 263.9	7.0 7.0
RC142	Unplated	215.7 213.8 213.4 211.9	253.8 254.7 253.7 251.5	4.6 6.2 6.2 6.2
	Copper plated	218.1 280.2	259.5 260.4	7.0 7.0
RC143	Unplated	212.8 207.4 212.2 209.9	251.6 244.6 250.0 245.8	7.0 7.0 7.0 6.5
	Copper plated	210.1 219.1	263.5 258.1	6.5 6.5
RC144	Unplated	212.8 210.9 217.3 213.3	254.8 252.9 257.6 254.4	6.0 7.0 6.0 6.0
	Copper plated	222.2 222.8	263.3 265.7	7.5 6.0
RC145	Unplated	215.5 215.6 215.1 210.7	254.7 257.0 257.9 254.0	6.0 6.0 7.0 7.0
	Copper plated	220.2 220.7	261.1 262.2	6.5 6.5
RC146	Unplated	215.1 213.1 214.7 215.2	257.0 253.6 255.2 255.1	6.0 6.0 6.0 6.0
	Copper plated	222.2 222.9	262.2 262.6	6.5 6.5

TABLE 4

PROOF TESTING DATA
NIKE-ZEUS - SECOND STAGE - P/N 5682968

MOTOR CASE NO.	DATE OF TEST	MINIMUM SECTION THICKNESS INCHES	MAXIMUM PRESSURE PSIG	THEORETICAL HOOP STRESS IN CYLINDER $f = \frac{Pr^*}{t}$ PSI
RC141	1-24-62	.115	1514	237,000
RC142	2-5-62	.111	1461	237,000
RC143	3-28-62	.112	1475	237,000
RC144	2-2-62	.113	1488	237,000
RC145	4-13-62	.114	1501	237,000
RC146	3-28-62	.113	1488	237,000

* r = 18 inches

SECTION VII

FIGURES

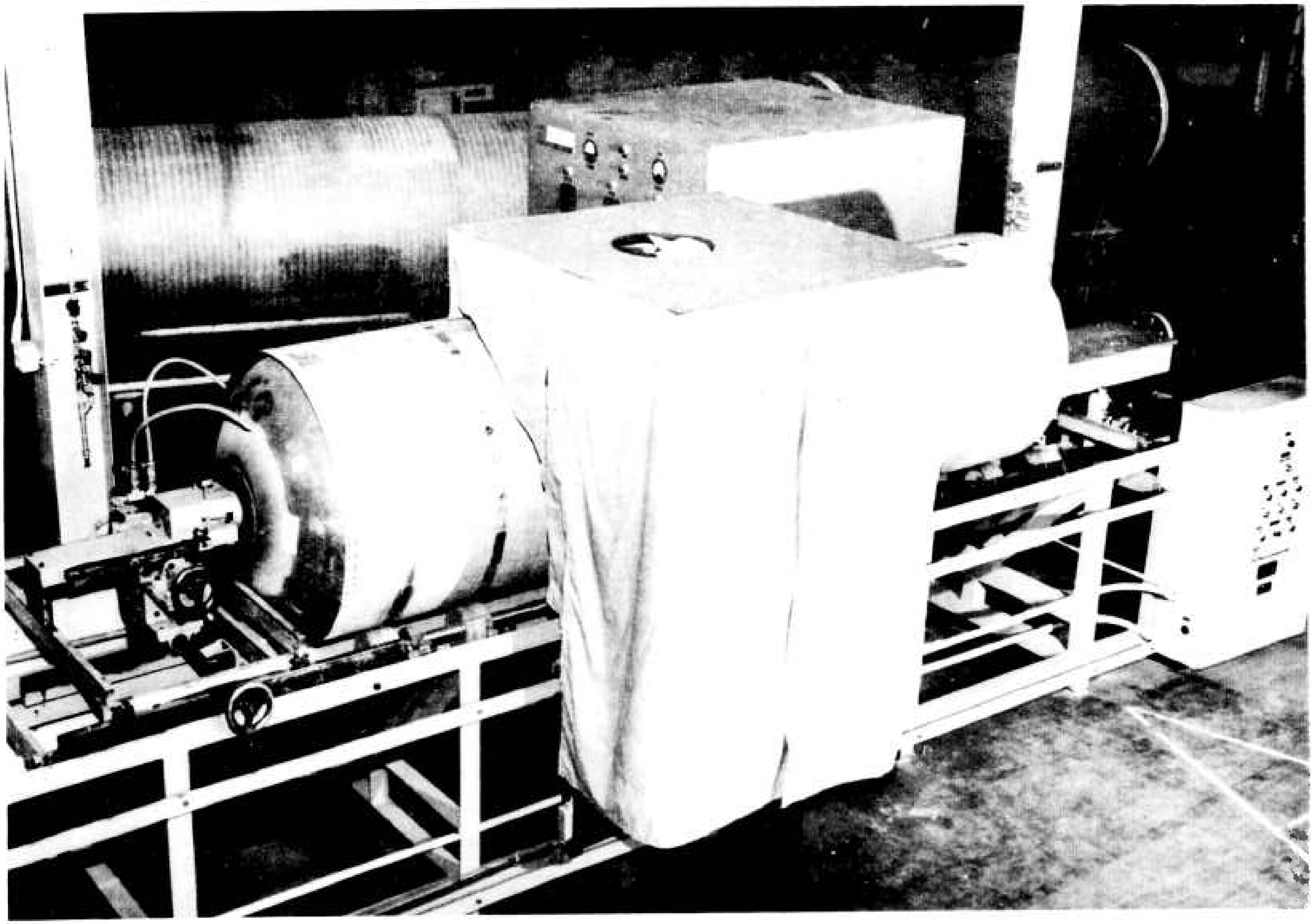

FIGURE 1

Motor case positioned on the magnetic particle inspection unit.

FIGURE 2

Motor case on the inspection stand in the inverted position with the cone end up.

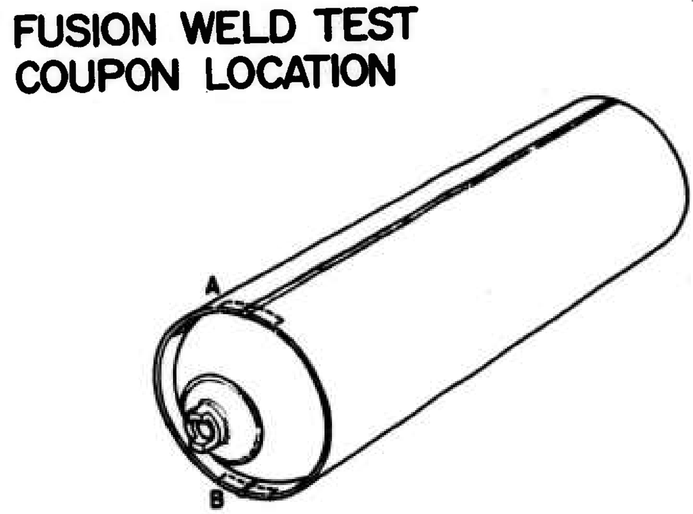

FIGURE 3

Location of fusion weld control test coupon cut from trim area.

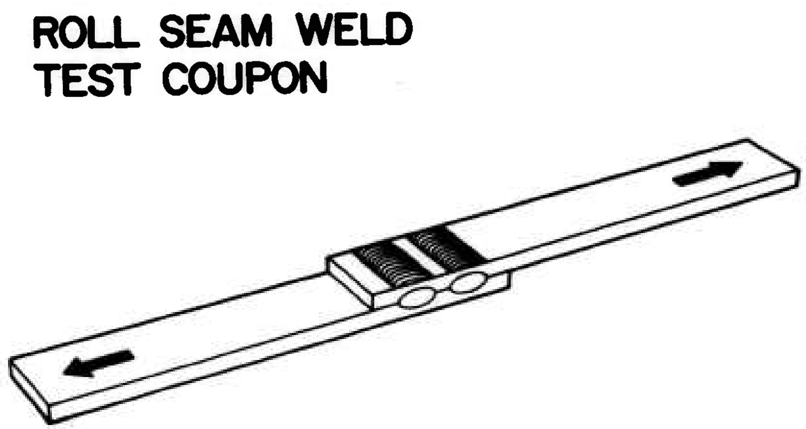

FIGURE 4

Special resistance seam weld control test coupon.

SECTION VIII

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